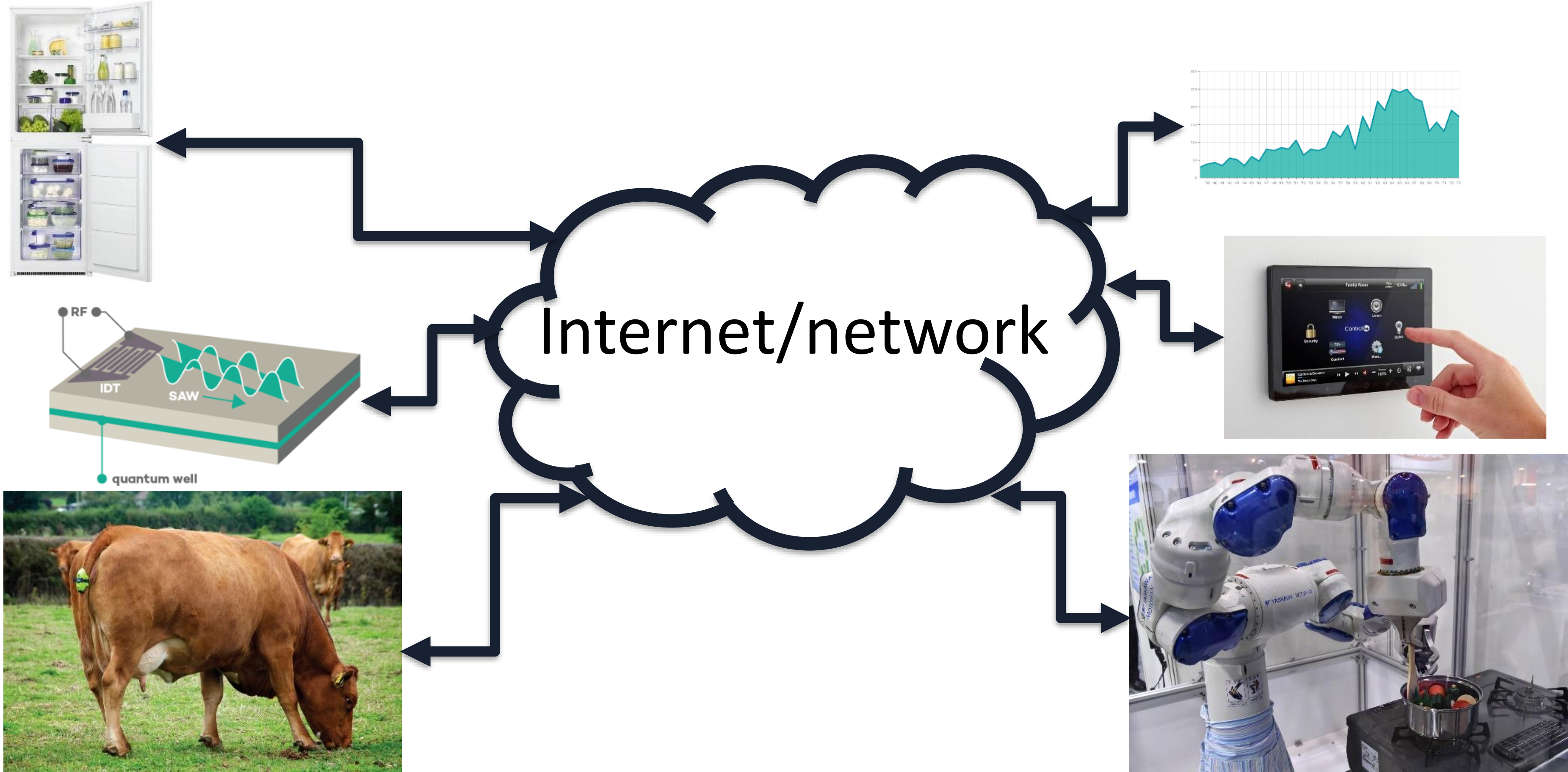
EEU44C04 / CS4031 / CS7NS3 / EEP55C27
Next Generation Networks

Internet of Things

Nicola Marchetti

nicola.marchetti@tcd.ie


Internet/network
RF
IDT
SAW
quantum well

Internet of Things (IoT)

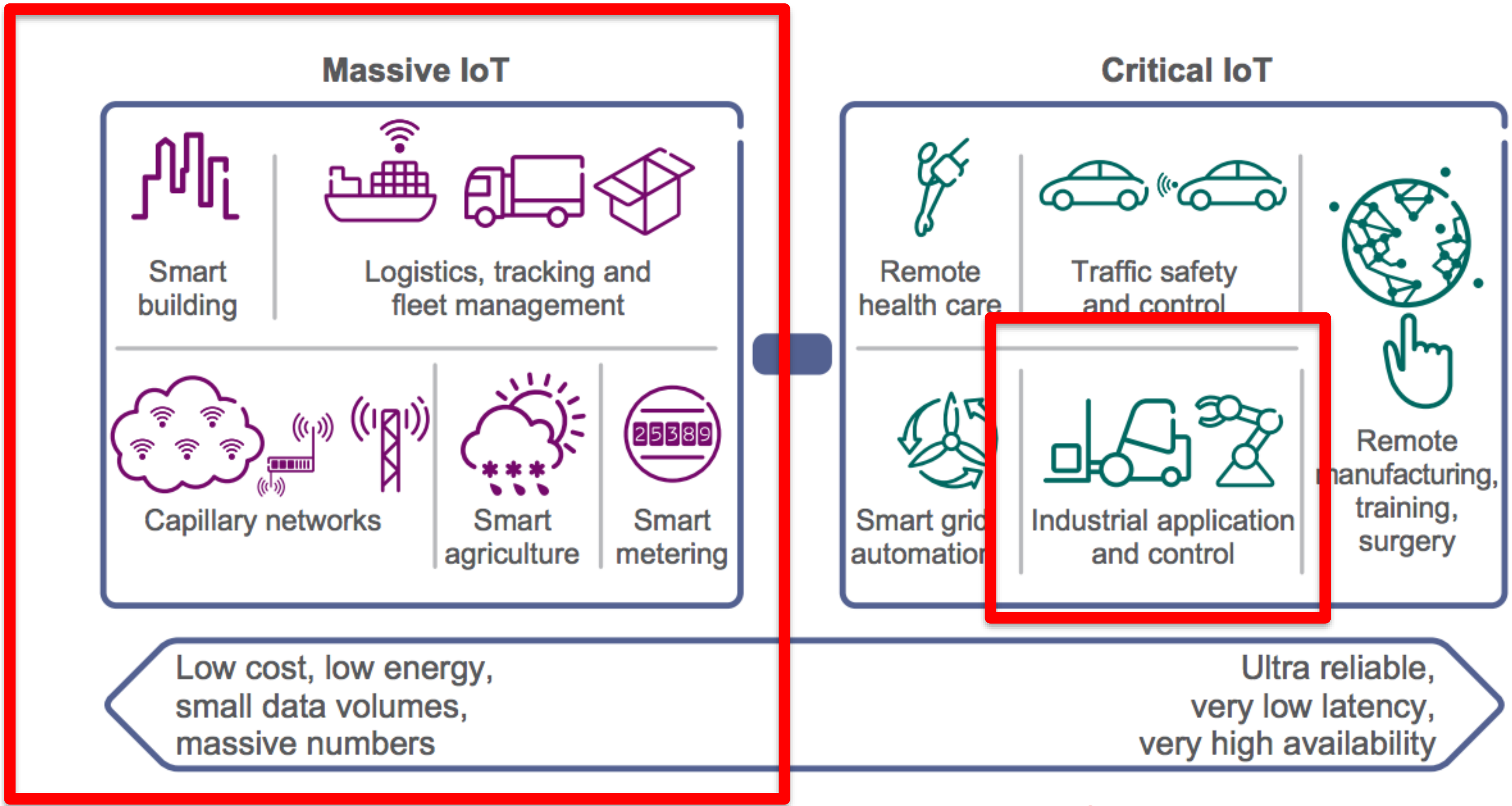
Industrial Internet of Things (IIoT)

Machine-to-Machine (M2M)

Machine-Type Communications (MTC)

All variations on a theme

Solutions available NOW FUTURE



Industrie 4.0

MTC requirements

The requirements of machine-type communication (MTC) vary considerably. At one end of the scale lies **massive MTC**, with **critical MTC** services at the other end.

Massive MTC

Examples that fall into this use-case category include the monitoring and automation of buildings and infrastructure, smart agriculture, logistics, tracking and fleet management. The **requirements for massive MTC include**:

- Architecturally simple devices that use a low-complexity transmission mode
- Devices that can run on battery power for many years
- Long transmission ranges for devices in remote locations
- Scalable networks that can connect either a large or a small number of M2M devices

Massive IoT/MTC

- Services that typically span a **very large numbers of devices, usually sensors and actuators**
- Sensors are extremely **low cost** and consume very low amounts of energy in order to sustain **long battery life**. Amount of data generated by each sensor is normally very small, and very low latency is not a critical requirement
- Actuators are similarly limited in cost, have varying energy footprints ranging from very low to moderate energy consumption
- Sometimes, a **mobile network may be used to bridge connectivity** to the device by means of *capillary networks*. Local connectivity is provided by means of a short-range radio access technology, e.g., Wi-Fi or Bluetooth. Wireless connectivity beyond the local area is then provided by the mobile network via a gateway node

Critical IoT (and the challenges for 5G)

- Refers to applications such as **traffic safety/control, control of critical infrastructure and wireless connectivity for industrial processes**
- Industries that can benefit from this vary from **automotive** (communication for control between and to/from cars), **energy utilities** (SCADA - Supervisory Control And Data Acquisition - control on the grid) and **Industrie 4.0** (control and communications in factories)
- In this type of communication, monitoring and control occur in **real-time**, End to End (E2E) latency requirements are very stringent – at millisecond levels – and the need for reliability is high
- Such applications require **very high reliability and availability** in terms of wireless connectivity, as well as very low latency
- On the other hand, low device cost and energy consumption are not as important as for Massive IoT applications
- While the average volume of data transported to and from devices may not be large, **wide instantaneous bandwidths** are useful in being able to meet **capacity and latency** requirements

Critical IoT (and the challenges for 5G)

- 5G has the aim of supporting these new classes of users in industry. These verticals have very stringent demands. Rather than depending on mobile networks solely for data communications, they are also looking for **wireless control**
- The main features that differentiate 5G from existing features of 4G in support of this transition are **increased resilience and robustness** of links (99.999% or more uptime) and **ultra low-latency** (< 5ms round trip times)
- The automation of energy distribution in a smart grid exemplifies the critical MTC/IoT case
  - In this case, the energy sources are volatile and distributed
  - The grid needs to match the dynamics of volatile energy supply with demand, to protect the overall grid against faults that can occur

Critical IoT (and the challenges for 5G)

- Supporting the automotive industry means increased support for **critical device-to-device communications**
- The 5G radio access can guarantee low latencies, and a network slice can be configured so that network and application **functions are physically placed in the network to ensure low latency, high reliability and redundancy E2E**
- To address various sectors, 5G networks will have
  - to be highly customisable – allowing for network slicing
  - to have **points of presence for data storage/computation much closer to where the control is required** – to address the latency objectives
- Concepts such the Mobile Edge Computing/Fog Computing may be deployed to service this

Supporting both Massive and Critical IoT (the bigger challenge for 5G)

- There is much to gain from a **network being able to handle as many different applications as possible**, including mobile broadband, media delivery and a wide range of IoT applications, by means of the **same basic wireless-access technology and within the same spectrum**

- This avoids spectrum fragmentation and allows operators to offer support for new IoT services for which the business potential is inherently uncertain, **without having to deploy a separate network** and to reassign spectrum specifically for these applications

Supporting both Massive and Critical IoT (the bigger challenge for 5G)

- Network slices that support IoT’s need for scalability can be optimized and support the introduction of leaner procedures such as **reduced signaling**

- This is a significant aim, as signaling is the dominant part of the overall traffic (and consequently battery consumption) compared with the actual data transferred by **massive IoT** devices

Low Power Wide Area Networks (LPWAN)

- ✓ Technology that supports **small messages** with specific duty cycles
- ✓ Supports low power end nodes and hence **long battery life** (**10 years**)
- ✓ Suited to **accessing sensors in awkward spots** (in-building 500m-3km and rural up to 30km)
- ✓ Cost point that suits the end applications
- ✓ Supports the creation of public networks that serve multiple uses and users

LPWAN aims

- The aim of this type of technology is to support a **vast number of cheap devices that transmit bursty, small, infrequent messages**
- LPWANs have a similar topology to mobile networks, with the aim of **better range and penetration**, through lower frequencies and more robust signals
- Typically, LPWANs aim to exceed the radio link budget performance of 2G's GPRS by 20 dB
- **Estimates** range from 50,000 to 100,000 devices per square kilometre/cell in Non-Line Of Sight (NLOS) urban areas
- In LOS situations the aim is to achieve > ~15km range. Typically, they operate in **sub-1GHz** so that the system can access **Things** placed deep indoors, i.e., in basements

LPWAN aims

- Maintaining cheap devices in the field on one battery for 10 years means that the **bill of materials (BOM)** for the devices must be very low if they are to be deployed at scale
- This presents challenges for the radio design – it must be pared back to the bare **minimum from a cost and power usage** point of view. Battery based operation impacts the amount of **handshaking** a device should do to preserve long life, which has a direct impact on achievable **QoS** levels
- The MAC also presents a challenge as the difficulty for the base stations is that they need to be able to **allow thousands of devices to connect with small messages, rather than the current situation of fewer devices and larger capacity demands** and longer sessions

LPWAN aims

- **Challenges also centre around the immaturity of the application space**. Accordingly, not much is known about the traffic profiles of different use cases, i.e., how often devices will transmit and how much data they will want to transmit

- The absence of traffic maturity creates difficulties in designing MAC/network schemes that support emerging applications. This contrasts with video/voice on existing networks– well known growth and usage patterns

LoRa = Long Range

RPMA = Random phase multiple access

Different flavours of LPWAN

Unlicensed spectrum < 1 GHz

2.4 GHz
ISM Band

Licensed
spectrum

LTE NB-IOT = Long Term Evolution Narrowband Internet of things

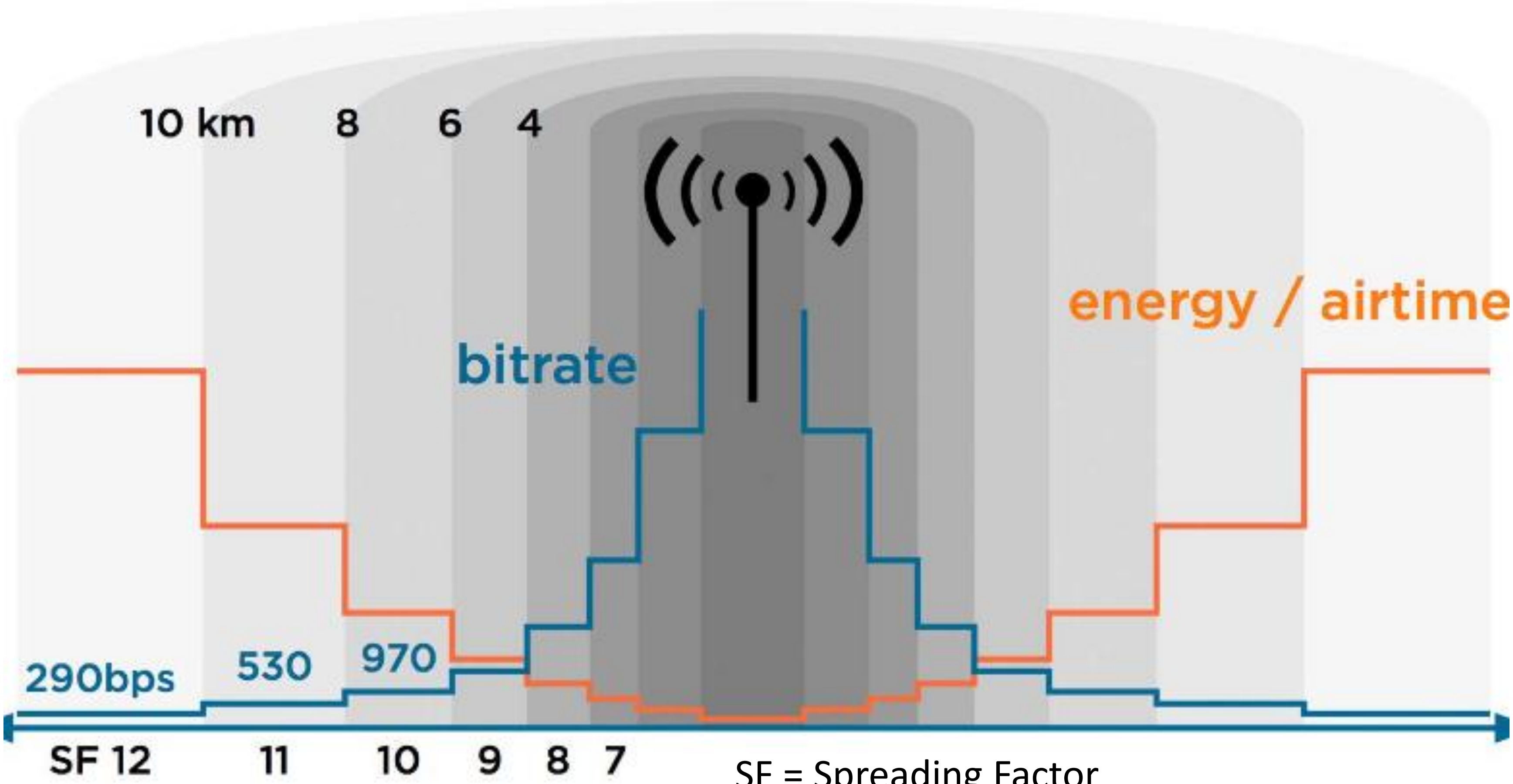
LoRa (Long Range)

- LoRa operates in the **868 MHz band which gives favourable propagation characteristics** to travel long distances by Line of Sight (LOS) or to penetrate Non-LOS (NLOS) situations
- As it operates in unlicensed spectrum that means that **anyone can deploy a base station** to service their needs in different scenarios, e.g., smart agriculture, smart city, etc, without relying on mobile operators → **similar innovation potential to Wi-Fi**
- However, this also has the impact of **uncertain QoS** in the band, as it is only controlled by lightweight duty-cycle and power rules originally designed for Short Range Devices, unlike an LPWAN deployed in licensed spectrum → **ETSI rules**

LoRa

- LoRa achieves a **large link budget** (range/penetration) by using **spread spectrum**-based PHY
- It also allows for different spreading factors (how robustly the data is encoded in the signal) which can be selected in an automatic adaptive fashion
- This **allows the LPWAN cells to breathe** (see next slide)
- LoRa Things use a simple Pure ALOHA MAC (for the uplink) which makes their operation **very simple** from a power and computation point of view → However, this is not a robust MAC, which means the **QoS is difficult** or costly in terms of handshaking
- Bidirectional communication is initiated by the **Thing** – not the base station

Adaptive Data Rate

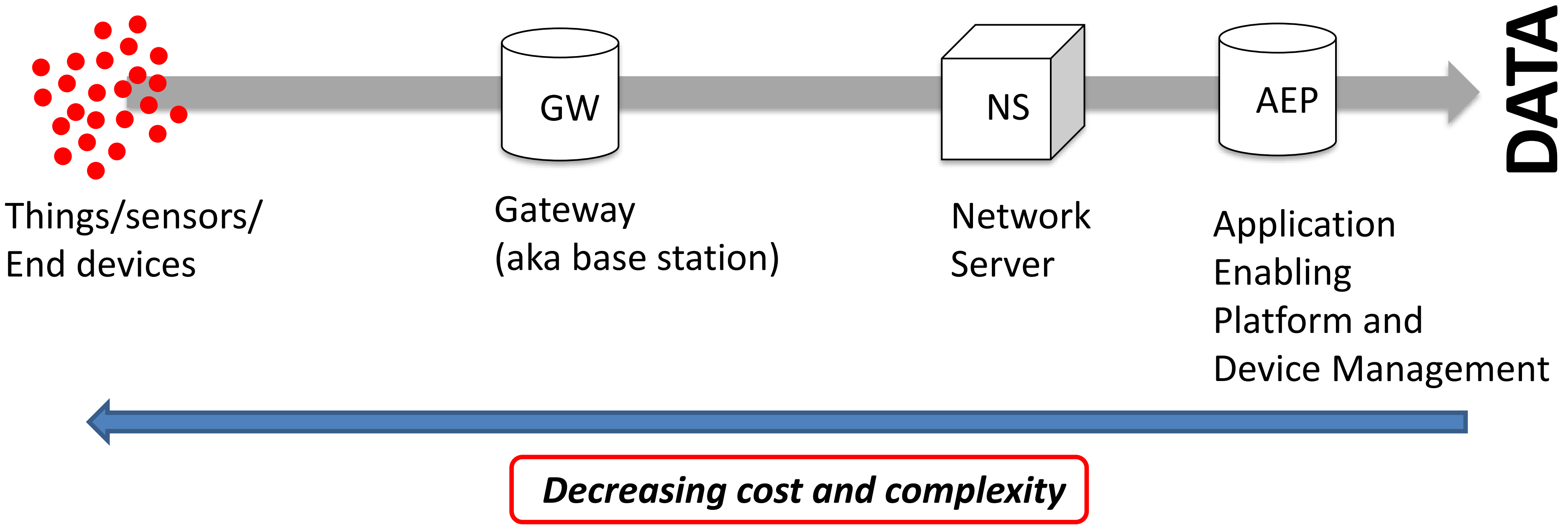


SF = Spreading Factor

LoRa at a glance

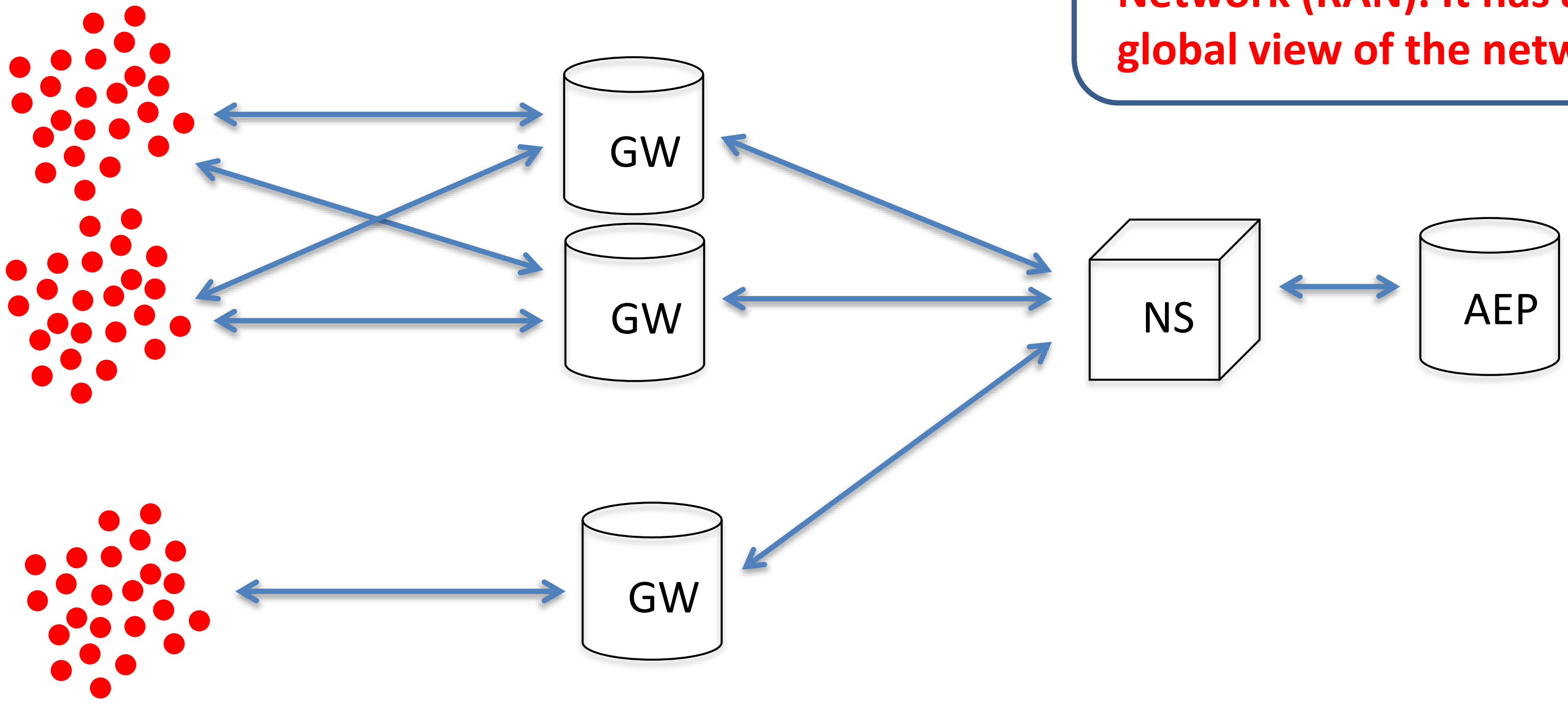
- 868 MHz technology (Europe)
- Spread spectrum based (very robust to noise)
- Bidirectional
- **250 bps to 50 kbps**
- **Up to 154 dB link budget**
- **Battery based end-devices**

LoRa - basic building blocks



Deployment scenario

The network server controls a centralized Radio Access Network (RAN). It has a global view of the network.

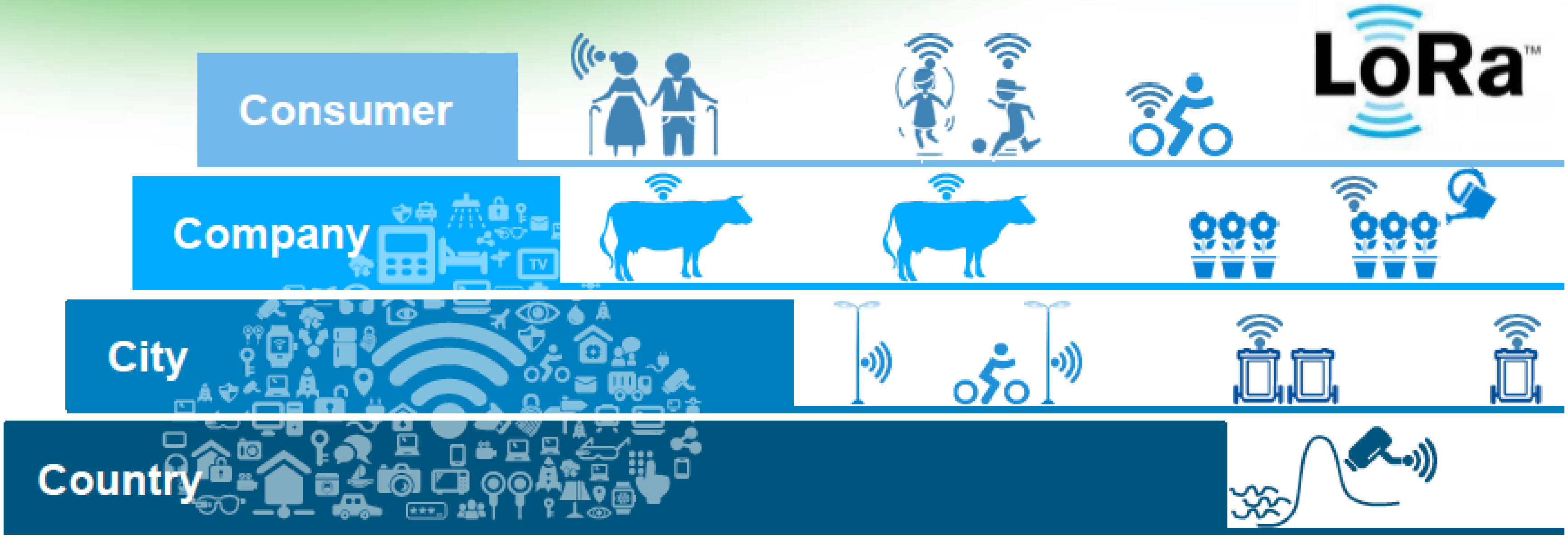


Trees, rainfall, flooding

Sound monitoring

Pervasive Nation

The Internet of Things is everywhere



kpn

Low Power Wide Area Networks (LPWAN) is:

- ❑ A technology that supports small messages with specific duty cycles
- ❑ A technology that supports high power end nodes and hence long battery life
- ❑ A technology that is suited to accessing sensors over a short range

Low Power Wide Area Networks (LPWAN) is:

- ❑ **A technology that supports small messages with specific duty cycles**
- ❑ A technology that supports high power end nodes and hence long battery life
- ❑ A technology that is suited to accessing sensors over a short range